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FOR

IMPROVED HARD BIAS STRUCTURE WITH ANTIPARALLEL LAYERS

INVENTOR(S):
Hardayal Singh Gill

ASSIGNEE: HITACHI GLOBAL STORAGE TECHNOLOGIES

SILICON VALLEY IP GROUP, PC
P.O. BOX 721120
SAN JOSE, CA 95172

IMPROVED HARD BIAS STRUCTURE WITH ANTIPARALLEL LAYERS

FIELD OF THE INVENTION

The present invention relates to magnetic heads, and more particularly, this invention relates to read heads having hard bias layers with enhanced pinning of free layers in the hard bias layers.

BACKGROUND OF THE INVENTION

The heart of a computer is a magnetic disk drive which includes a rotating magnetic disk, a slider that has read and write heads, a suspension arm above the rotating disk and an actuator arm that swings the suspension arm to place the read and write heads over selected circular tracks on the rotating disk. The suspension arm biases the slider into contact with the surface of the disk when the disk is not rotating but, when the disk rotates, air is swirled by the rotating disk adjacent an air bearing surface (ABS) of the slider causing the slider to ride on an air bearing a slight distance from the surface of the rotating disk. When the slider rides on the air bearing the write and read heads are employed for writing magnetic impressions to and reading magnetic signal fields from the rotating disk. The read and write heads are connected to processing circuitry that

operates according to a computer program to implement the writing and reading functions.

In high capacity disk drives, magnetoresistive (MR) read sensors, commonly referred to as MR heads, are the prevailing read sensors because of their capability to read data from a surface of a disk at greater track and linear densities than thin film inductive heads. An MR sensor detects a magnetic field through the change in the resistance of its MR sensing layer (also referred to as an "MR element") as a function of the strength and direction of the magnetic flux being sensed by the MR layer.

The conventional MR sensor operates on the basis of the anisotropic magnetoresistive (AMR) effect in which an MR element resistance varies as the square of the cosine of the angle between the magnetization in the MR element and the direction of sense current flow through the MR element. Recorded data can be read from a magnetic medium because the external magnetic field from the recorded magnetic medium (the signal field) causes a change in the direction of magnetization of the MR element, which in turn causes a change in resistance of the MR element and a corresponding change in the sensed current or voltage.

Another type of MR sensor is the giant magnetoresistance (GMR) sensor manifesting the GMR effect. In GMR sensors, the resistance of the GMR sensor varies as a function of the spin-dependent transmission of the conduction electrons between ferromagnetic layers separated by a non-magnetic layer (spacer) and the accompanying spin-dependent scattering which takes place at the interface of the ferromagnetic and non-magnetic layers and within the ferromagnetic layers.

GMR sensors using only two layers of ferromagnetic material (e.g., Ni-Fe) separated by a layer of non-magnetic material (e.g., copper) are generally referred to as spin valve (SV) sensors. In an SV sensor, one of the ferromagnetic layers, referred to as the pinned layer (reference layer), has its magnetization typically pinned by exchange coupling with an antiferromagnetic (e.g., NiO or Fe-Mn) layer. The pinning field generated by the antiferromagnetic layer should be greater than demagnetizing fields (about 200 Oe) at the operating temperature of the SV sensor (about 120° C) to ensure that the magnetization direction of the pinned layer remains fixed during the application of external fields (e.g., fields from bits recorded on the disk). The magnetization of the other ferromagnetic layer, referred to as the free layer, however, is not fixed and is free to rotate in response to the field from the recorded magnetic medium (the signal field). U.S. Pat. No. 5,206,590 granted to Dieny et al., incorporated herein by reference, discloses a SV sensor operating on the basis of the GMR effect.

An exemplary high performance read head employs a spin valve sensor for sensing the magnetic signal fields from the rotating magnetic disk. FIG. **1A** shows a prior art SV sensor **100** comprising a free layer (free ferromagnetic layer) **110** separated from a pinned layer (pinned ferromagnetic layer) **120** by a non-magnetic, electrically-conducting spacer layer **115**. The magnetization of the pinned layer **120** is fixed by an antiferromagnetic (AFM) layer **130**.

FIG. **1B** shows another prior art SV sensor **150** with a flux keepered configuration. The SV sensor **150** is substantially identical to the SV sensor **100** shown in FIG. **1A** except for the addition of a keeper layer **152** formed of ferromagnetic material separated from the free layer **110** by a non-magnetic spacer layer **154**. The keeper layer

152 provides a flux closure path for the magnetic field from the pinned layer **120** resulting in reduced magnetostatic interaction of the pinned layer **120** with the free layer **110**. U.S. Pat. No. 5,508,867 granted to Cain et al., incorporated herein by reference, discloses a SV sensor having a flux keepered configuration.

Another type of SV sensor is an antiparallel (AP)-pinned SV sensor. In AP-Pinned SV sensors, the pinned layer is a laminated structure of two ferromagnetic layers separated by a non-magnetic coupling layer such that the magnetizations of the two ferromagnetic layers are strongly coupled together antiferromagnetically in an antiparallel orientation. The AP-Pinned SV sensor provides improved exchange coupling of the antiferromagnetic (AFM) layer to the laminated pinned layer structure than is achieved with the pinned layer structure of the SV sensor of FIG. **1A**. This improved exchange coupling increases the stability of the AP-Pinned SV sensor at high temperatures which allows the use of corrosion resistant antiferromagnetic materials such as NiO for the AFM layer.

Referring to FIG. **2A**, an AP-Pinned SV sensor **200** comprises a free layer **210** separated from a laminated AP-pinned layer structure **220** by a nonmagnetic, electrically-conducting spacer layer **215**. The magnetization of the laminated AP-pinned layer structure **220** is fixed by an AFM layer **230**. The laminated AP-pinned layer structure **220** comprises a first ferromagnetic layer **226** and a second ferromagnetic layer **222** separated by an antiparallel coupling layer (APC) **224** of nonmagnetic material. The two ferromagnetic layers **226**, **222** (FM_1 and FM_2) in the laminated AP-pinned layer structure **220** have their magnetization directions oriented antiparallel, as indicated by the arrows **227**, **223** (arrows pointing out of and into the plane of the paper respectively).

A key requirement for optimal operation of an SV sensor is that the pinned layer should be magnetically saturated perpendicular to the air bearing surface. Lack of magnetic saturation in the pinned layer leads to reduced signal or dynamic range. Factors leading to a loss of saturation include demagnetizing fields at the edge of the pinned layer, magnetic fields from recorded data and from longitudinal biasing regions, current induced fields and the coupling field to the free layer.

Analysis of the magnetic state of pinned layers in small sensors (a few microns or less in width), reveals that due primarily to the presence of large demagnetizing fields at the sensor edges the magnetization is not uniform over the area of the pinned layer. FIG. **2B** shows a perspective view of an SV sensor **250**. The SV sensor **250** is formed of a sensor stripe **260** having a front edge **270** at the ABS and extending away from the ABS to a rear edge **272**. Due to the large demagnetizing fields at the front edge **270** and the rear edge **272** of the sensor stripe **260**, the desired perpendicular magnetization direction is achieved only at the center portion **280** of the pinned layer stripe, while the magnetization tends to be curled into a direction parallel to the ABS at the edges of the stripe. The extent of these curled regions is controlled by the magnetic stiffness of the pinned layer.

Furthermore, prior art AP-Pinned SV sensors use an AFM in order to pin the pinned layer magnetization. Most commonly used AFM materials have blocking temperatures (temperature at which the pinning field reaches zero Oe) near 200° C. This means that if the temperature of the SV sensor approaches this temperature, the pinned layer magnetization can change its orientation resulting in degraded SV sensor performance.

Although AP-Pinned SV sensors have large effective pinning fields because near cancellation of the magnetic moments of the two sub-layers results in a low net magnetic moment for the pinned layer, thermal stability is still a concern because the operating temperatures of these SV sensors in disk files can exceed 120° C. In addition, the AP-pinned layer structure is vulnerable to demagnetization during processing operations such as lapping.

Therefore there is a need for an SV sensor that increases the magnetic saturation of the pinned layer and reduces the sensitivity to demagnetizing fields particularly at the front and rear edges of the pinned layer stripe. In SV sensors that include AFM layers to provide exchange anisotropy fields to fix the pinned layer magnetization direction, there is a further need for an SV structure that reduces the temperature limitations imposed by the blocking temperature characteristics of the commonly used antiferromagnetic materials required in prior art SV sensors for providing pinning fields.

In any of the prior art sensors described above, the thickness of the spacer layer is chosen so that shunting of the sense current and a magnetic coupling between the free and pinned layer structures are minimized. This thickness is typically less than the mean free path of electrons conducted through the sensor. With this arrangement, a portion of the conduction electrons are scattered at the interfaces of the spacer layer with the pinned and free layer structures. When the magnetic moments of the pinned and free layer structures are parallel with respect to one another scattering is minimal and when their magnetic moments are antiparallel scattering is maximized. Changes in scattering changes the resistance of the spin valve sensor as a function of cos Θ, where Θ is the angle between the magnetic moments of the pinned and free layer structures. The

sensitivity of the sensor is quantified as magnetoresistive coefficient dr/R where dr is the change in the resistance of the sensor as the magnetic moment of the free layer structure rotates from a position parallel with respect to the magnetic moment of the pinned layer structure to an antiparallel position with respect thereto and R is the resistance of the sensor when the magnetic moments are parallel.

The transfer curve of a spin valve sensor is defined by the aforementioned cos Θ where Θ is the angle between the directions of the magnetic moments of the free and pinned layers. In a spin valve sensor subjected to positive and negative magnetic signal fields from a moving magnetic disk, which are typically chosen to be equal in magnitude, it is desirable that positive and negative changes in the resistance of the spin valve read head above and below a bias point on the transfer curve of the sensor be equal so that the positive and negative readback signals are equal. When the direction of the magnetic moment of the free layer is substantially parallel to the ABS and the direction of the magnetic moment of the pinned layer is perpendicular to the ABS in a quiescent state (no signal from the magnetic disk) the positive and negative readback signals should be equal when sensing positive and negative fields from the magnetic disk.

Accordingly, the bias point should be located midway between the top and bottom of the transfer curve. When the bias point is located below the midway point the spin valve sensor is negatively biased and has positive asymmetry and when the bias point is above the midway point the spin valve sensor is positively biased and has negative asymmetry. When the readback signals are asymmetrical, signal output and dynamic range of the sensor are reduced. Readback asymmetry is defined as:

$$\frac{V_1 - V_2}{\max(V_1 \text{ or } V_2)}$$

For example, +10% readback asymmetry means that the positive readback signal V_1 is 10% greater than it should be to obtain readback symmetry. 10% readback asymmetry is acceptable in some applications. +10% readback asymmetry may not be acceptable in applications where the applied field magnetizes the free layer close to saturation. The designer strives to improve asymmetry of the readback signals as much as practical with the goal being symmetry.

The location of the transfer curve relative to the bias point is influenced by four major forces on the free layer of a spin valve sensor, namely a ferromagnetic coupling field H_{FC} between the pinned layer and the free layer, a net demagnetizing (demag) field H_D from the pinned layer, a sense current field H_I from all conductive layers of the spin valve except the free layer, a net image current field H_{IM} from the first and second shield layers.

What is needed is an antiparallel hard bias structure which provides stronger pinning compared to conventional hard bias structures using hard bias layers.

SUMMARY OF THE INVENTION

A magnetic head according to a preferred embodiment includes a sensor with a free layer, the free layer having a magnetic moment. Hard bias structures are positioned towards opposite ends of the sensor, the hard bias structures stabilizing the magnetic moment of the free layer. Each hard bias structure includes an antiparallel (AP) pinned layer structure and an antiferromagnetic layer positioned towards each of the AP pinned layer structures. Each AP pinned layer structure has a middle pinned layer aligned along a plane of the free layer of the sensor, and outer pinned layers positioned on opposite sides of the middle pinned layer. Each antiferromagnetic layer stabilizes a magnetic moment of the pinned layer closest thereto.

Preferably, a net magnetic moment of the AP pinned layer structure is about zero. Also preferably, a thickness of the middle pinned layer is at least as thick as the free layer of the sensor, and may be twice as thick as the free layer of the sensor or more.

In a preferred embodiment, the outer pinned layers are misaligned from the free layer. The pinned layers of the AP pinned layer structure may each include at least Co and are separated by a layer of Ru. The antiferromagnetic layers may each include PtMn and/or IrMn.

The heads described herein may form part of a GMR head, a CIP GMR head, a CPP GMR head, a tunnel valve head, etc. for use in a magnetic storage system.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and advantages of the present invention, as well as the preferred mode of use, reference should be made to the following detailed description read in conjunction with the accompanying drawings.

FIG. **1A** is an air bearing surface view, not to scale, of a prior art spin valve (SV) sensor.

FIG. **1B** is an air bearing surface view, not to scale, of a prior art keepered SV sensor.

FIG. **2A** is an air bearing surface view, not to scale, of a prior art AP-Pinned SV sensor.

FIG. **2B** is a perspective view, not to scale, of a prior art AP-Pinned SV sensor.

FIG. **3** is a simplified drawing of a magnetic recording disk drive system.

FIG. **4** is a partial view of the slider and a merged magnetic head.

FIG. **5** is a partial ABS view, not to scale, of the slider taken along plane **5-5** of FIG. **4** to show the read and write elements of the merged magnetic head.

FIG. **6** is an enlarged isometric illustration, not to scale, of the read head with a spin valve sensor.

FIG. **7** is an ABS illustration of a sensor structure, not to scale, according to one embodiment of the present invention.

FIG. **8** is an ABS illustration of a sensor structure, not to scale, according to another embodiment of the present invention.

FIG. **9** is an ABS illustration of a sensor structure, not to scale, according to yet another embodiment of the present invention.

FIG. **10** is an ABS illustration of a sensor, not to scale, according to an embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

The following description is the best embodiment presently contemplated for carrying out the present invention. This description is made for the purpose of illustrating the general principles of the present invention and is not meant to limit the inventive concepts claimed herein.

Referring now to FIG. **3**, there is shown a disk drive **300** embodying the present invention. As shown in FIG. **3**, at least one rotatable magnetic disk **312** is supported on a spindle **314** and rotated by a disk drive motor **318**. The magnetic recording on each disk is in the form of an annular pattern of concentric data tracks (not shown) on the disk **312**.

At least one slider **313** is positioned near the disk **312**, each slider **313** supporting one or more magnetic read/write heads **321**. More information regarding such heads **321** will be set forth hereinafter during reference to FIG. **4**. As the disks rotate, slider **313** is moved radially in and out over disk surface **322** so that heads **321** may access different tracks of the disk where desired data are recorded. Each slider **313** is attached to an actuator arm **319** by means way of a suspension **315**. The suspension **315** provides a slight spring force which biases slider **313** against the disk surface **322**. Each actuator arm **319** is attached to an actuator means **327**. The actuator means **327** as shown in FIG. **3** may be a voice coil motor (VCM). The VCM comprises a coil movable within a fixed magnetic field, the direction and speed of the coil movements being controlled by the motor current signals supplied by controller **329**.

During operation of the disk storage system, the rotation of disk **312** generates an air bearing between slider **313** and disk surface **322** which exerts an upward force or lift on the slider. The air bearing thus counter-balances the slight spring force of suspension **315** and supports slider **313** off and slightly above the disk surface by a small, substantially constant spacing during normal operation.

The various components of the disk storage system are controlled in operation by control signals generated by control unit **329**, such as access control signals and internal clock signals. Typically, control unit **329** comprises logic control circuits, storage means and a microprocessor. The control unit **329** generates control signals to control various system operations such as drive motor control signals on line **323** and head position and seek control signals on line **328**. The control signals on line **328** provide the desired current profiles to optimally move and position slider **313** to the desired data track on disk **312**. Read and write signals are communicated to and from read/write heads **321** by way of recording channel **325**.

The above description of a typical magnetic disk storage system, and the accompanying illustration of FIG. **3** are for representation purposes only. It should be apparent that disk storage systems may contain a large number of disks and actuators, and each actuator may support a number of sliders.

FIG. **4** is a side cross-sectional elevation view of a merged magnetic head **400**, which includes a write head portion **402** and a read head portion **404**, the read head portion employing a dual spin valve sensor **406** of the present invention. FIG. **5** is an ABS view of FIG. **4**. The spin valve sensor **406** is sandwiched between nonmagnetic electrically insulative first and second read gap layers **408** and **410**, and the read gap

layers are sandwiched between ferromagnetic first and second shield layers **412** and **414**. In response to external magnetic fields, the resistance of the spin valve sensor **406** changes. A sense current (I_s) conducted through the sensor causes these resistance changes to be manifested as potential changes. These potential changes are then processed as readback signals by the processing circuitry **329** shown in FIG. **3**.

The write head portion **402** of the magnetic head **400** includes a coil layer **422** sandwiched between first and second insulation layers **416** and **418**. A third insulation layer **420** may be employed for planarizing the head to eliminate ripples in the second insulation layer caused by the coil layer **422**. The first, second and third insulation layers are referred to in the art as an "insulation stack". The coil layer **422** and the first, second and third insulation layers **416**, **418** and **420** are sandwiched between first and second pole piece layers **424** and **426**. The first and second pole piece layers **424** and **426** are magnetically coupled at a back gap **428** and have first and second pole tips **430** and **432** which are separated by a write gap layer **434** at the ABS. Since the second shield layer **414** and the first pole piece layer **424** are a common layer this head is known as a merged head. In a piggyback head an insulation layer is located between a second shield layer and a first pole piece layer. First and second solder connections (not shown) connect leads (not shown) from the spin valve sensor **406** to leads (not shown) on the slider **313** (FIG. **3**), and third and fourth solder connections (not shown) connect leads (not shown) from the coil **422** to leads (not shown) on the suspension.

FIG. **6** is an enlarged isometric ABS illustration of the read head **400** shown in FIG. **4**. The read head **400** includes the spin valve sensor **406**. First and second hard bias and lead layers **602** and **604** are connected to first and second side edges **606** and **608** of

the spin valve sensor. This connection is known in the art as a contiguous junction and is fully described in U.S. Pat. 5,018,037 which is incorporated by reference herein. The first hard bias and lead layers **602** include a first hard bias layer **610** and a first lead layer **612** and the second hard bias and lead layers **604** include a second hard bias layer **614** and a second lead layer **616**. The hard bias layers **610** and **614** cause magnetic fields to extend longitudinally through the spin valve sensor **406** for stabilizing the magnetic domains therein. The spin valve sensor **406** and the first and second hard bias and lead layers **602** and **604** are located between the nonmagnetic electrically insulative first and second read gap layers **408** and **410**. The first and second read gap layers **408** and **410** are, in turn, located between the ferromagnetic first and second shield layers **412** and **414**.

In the following description, the width of the layers (W) refers to the track width. The sensor height is in a direction into the face of the paper. Unless otherwise described, thicknesses of the individual layers are taken perpendicular to the plane of the associated layer and are provided by way of example only and may be larger and/or smaller than those listed. Similarly, the materials listed herein are provided by way of example only, and one skilled in the art will understand that other materials may be used without straying from the spirit and scope of the present invention.

FIG. **7** depicts an ABS view of a sensor structure **700** according to one embodiment. As shown, a sensor **702** is positioned between two bias structures **704**. Each bias structure **704** includes a trilayer AP pinned structure **706**, which provides the longitudinal bias to the free layer, and an AFM layer (AFM) **707** positioned above or below the AP pinned structure **706** to provide further pinning of the AP pinned structure

706. This new scheme provides very strong AP coupling and is also relatively independent of the substrate and seed layer crystal structure.

Referring to the structure itself, the sensor **702** can be a standard sensor **702** of any type. An illustrative sensor **702** is shown in FIG. **10**.

Each AP pinned structure **706** includes a middle pinned layer (MP) **708**. Upper and lower layers (UP, LP) **710, 712** (collectively, "outer pinned layers") are positioned above and below the middle pinned layer **708**. Illustrative materials from which the pinned layers **708-712** can be formed include Co, CoFe, etc. The spacer layers (SP) **714** separating the pinned layers **708-712** are preferably Ru, which creates the AP coupling between the pinned layers **708-712**. Note that the lower pinned layer **712** is below the sensor **702**, so milling into the substrate may need to be performed.

Ideally, the net magnetization of the AP pinned structure **706** is about zero, i.e., the sum of the magnetic thicknesses of the outer pinned layers **710**, **712** is about equal to the magnetic thickness of the middle pinned layer **708**. Thus, preferably, the outer pinned layers **710**, **712** each have about one half the magnetic thickness of the middle pinned layer **708**. This provides a net magnetic moment of the AP pinned structure **706** of about zero, providing the strongest pinning. If the same material is used for all three layers **708-712**, for example each outer layer **710**, **712** will have one half the physical thickness of the middle pinned layer **708**. For example, if the pinned layers **708-712** are CoFe, thicknesses of the outer pinned layers **710**, **712** can be about 50 Å and the thickness of the middle pinned layer **708** can be about 100 Å.

The AFM layer **707** provides exchange anisotropy fields to fix the magnetization direction of the pinned layer closest to it. Preferred materials for the AFM layer **707** are

PtMn and IrMn. The thickness of the AFM layer **707** can be about 100-150 Å if it is constructed from PtMn, and about 50-80 Å if it is constructed from IrMn, regardless of the thicknesses of the pinned layers **708-712**. The thickness of the AFM layer **707** is not important because the net moment of the AP structure **706** is about zero. The zero net moment of the AP structure **706** coupled with the additional pinning by the AFM layer **707** assures strong pinning. In fact, the pinned layers **708-712** are pinned so strongly that virtually no external magnetic or electrical force will be able to disrupt the magnetic orientations of the pinned layers **708-712**.

The purpose of the AP structure **706** is to provide bias to the sensor **702** to stabilize the free layer. However, because the net moment of the AP structure **706** is zero, it is undesirable for all of the pinned layers **708-712** to be positioned close to the sensor **702** because the net field applied to the sensor **702** will also be zero. Therefore, the middle pinned layer **708** is aligned with the free layer of the sensor **702** whereas the upper and lower layers **710, 712** are fully misaligned from the free layer. The alignment of the middle pinned layer **708** and misalignment of the outer layers **710, 712** provides strong local fields from the middle pinned layer **708** at either end of the sensor **702**, while fields from the outer pinned layers **710, 712** are minimized because they are not aligned with the sensor **702**. To maximize the field exerted on the sensor **702** by the middle pinned layer **708**, the middle pinned layer **708** can be made quite thick, such as about 100 Å. Then the outer pinned layers **710, 712**, if of the same material as the middle pinned layer **708**, would each be about 50 Å thick.

The fields from all of the pinned layers **708-712** will begin to superimpose towards the middle of the sensor **702**. However, the fields are weaker towards the middle

of the sensor **702** because of the superposition of the fields from the antiparallel magnetized layers. Thus, the bias structure scheme presented herein provides a high field at the ends of sensor **702** with minimal fields across the remainder of the sensor **702**. An additional benefit is that because the fields are weak away from the ends of the sensor **702**, the moment of the free layer will have maximum rotation, providing a strong signal during reading.

The thickness of the middle pinned layer **708** should be at least as thick as the free layer (typically about 30 Å) to provide adequate field to stabilize the free layer, and can be many times thicker than the free layer.

FIG. **8** illustrates a sensor structure **800** according to another embodiment. The structure **800** is similar to the structure **700** of FIG. **7**, except that the AP pinned structure **706** includes only two pinned layers **708, 710**. This structure **800** may be easier to manufacture, as no pinned layer need be positioned below the sensor **702**. In this embodiment, one pinned layer **708** is aligned with the sensor **702**. That pinned layer **708** is very thick so that the other pinned layer **710** is positioned away from the sensor **702**. Like the embodiment described above, this AP structure provides strong fields at the ends of the sensor **702**, and weak fields towards the middle of the sensor **702**.

FIG. **9** illustrates yet another sensor structure **900**. The structure **900** is similar to the structure **700** of FIG. **7**, except that no AFM layer is present. Like the embodiments described above, this AP structure provides strong fields at the ends of the sensor **702**, and weak fields away from the ends of the sensor **702**.

FIG. **10** illustrates an ABS view of a sensor **702** that can be used with the embodiments described herein. Note that other sensor configurations can also be used.

Seed layers are formed on the first layer of insulative material (G1) **1002**. The seed layers aid in creating the proper growth structure of the layers above them. Illustrative materials formed in a stack from the first shield layer **1002** are a layer of Ta (SL1-S) **1004**, a layer of NiFeCr (SL2-S) **1006**, a layer of NiFe (SL3-S) **1008** and a layer of PtMn (SL4-S) **1010**. Illustrative thicknesses of these materials are Ta (30Å), NiFeCr (20Å), NiFe (8Å), and PtMn (30Å). Note that the stack of seed layers can be varied, and layers may be added or omitted based on the desired processing parameters.

Then an antiparallel (SAP) pinned layer structure **1012** is formed above the seed layers. As shown in FIG. **10**, first and second AP pinned magnetic layers, (AP1-S) and (AP2-S) **1014, 1016**, are separated by a thin layer of an antiparallel coupling (APC-S) material **1018** such that the magnetic moments of the AP pinned layers **1014, 1016** are self-pinned antiparallel to each other. The pinned layers **1014, 1016** have a property known as magnetostriction. The magnetostriction of the pinned layers **1014, 1016** is very positive. The sensor **702** is also under compressive stresses because of its geometry at the ABS, and the configuration of the layer is such that it produces very large compressive stress. The combination of positive magnetostriction and compressive stress causes the pinned layers **1014, 1016** to develop a magnetic anisotropy that is in a perpendicular direction to the track width. This magnetic coupling through the Ru spacer causes the pinned layers **1014, 1016** to have antiparallel-oriented magnetizations.

In the embodiment shown in FIG. **10**, the preferred magnetic orientation of the pinned layers **1014, 1016** is for the first pinned layer **1014**, into the face of the structure depicted (perpendicular to the ABS of the sensor **702**), and out of the face for the second pinned layer **1016**. Illustrative materials for the pinned layers **1014, 1016** are $CoFe_{10}$

(100% Co, 10% Fe), $CoFe_{50}$ (50% Co, 50% Fe), etc. separated by a Ru layer **1018**. Illustrative thicknesses of the first and second pinned layers **1014, 1016** are between about 10Å and 25Å. The Ru layer **1018** can be about 5-15Å, but is preferably selected to provide a saturation field of above about 10 KOe, ideally about 200 Oe. In a preferred embodiment, each of the pinned layers **1014, 1016** is about 18Å with an Ru layer **1018** therebetween of about 8Å.

A first spacer layer (SP1-S) **1020** is formed above the pinned layer structure **1012**. Illustrative materials for the first spacer layer **1020** include Cu, CuO_x, Cu/$CoFeO_x$/Cu stack, etc. The first spacer layer **1020** can be about 10-30Å thick, preferably about 20Å.

A free layer (FL-S) **1022** is formed above the first spacer layer **1020**. The magnetic moment of the free layer **1022** is soft and so is susceptible to reorientation from external magnetic forces, such as those exerted by data on disk media. The relative motion of magnetic orientation of the free layer **1022** when affected by data bits on disk media creates variations in the sensing current flowing through the sensor **702**, thereby creating the signal. Exemplary materials for the free layer **1022** are CoFe/NiFe stack, etc. An illustrative thickness of the free layer **1022** is about 10-40Å.

The magnetic orientation of the free layer **1022** must be preset during manufacture, otherwise the orientation will be unstable and could move around at random, resulting in a "scrambled" or noisy signal. This instability is a fundamental property of soft materials, making them susceptible to any external magnetic perturbations. Thus, the magnetic orientation of the free layer **1022** should be stabilized so that when its magnetic orientation moves, it consistently moves around in a systematical manner rather than a random manner. The magnetic orientation of the free

layer **1022** should also be stabilized so that it is less susceptible to reorientation, i.e., reversing. The structure disclosed stabilizes the free layer **1022**.

A cap (CAP) **1028** can be formed above the free layer **1022**. Exemplary materials for the cap **1028** are Ta, Ta/Ru stack, etc. An illustrative thickness of the cap **1028** is 20-30Å. A second insulative layer (G2) **1030** is formed above the cap.

While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. For example, the structures and methodologies presented herein are generic in their application to all MR heads, AMR heads, GMR heads, spin valve heads, etc. Thus, the breadth and scope of a preferred embodiment should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.